New evidence from Italy (Adamello Group, Lombardy) for analysing the ongoing decline of Alpine glaciers

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Glaciers worldwide are showing overwhelming evidence of the impact of climatic change. In the Alpine region the warming experienced since the early 1980s, while synchronous with warming at the global scale, is of a far greater amplitude and exceeds 1 °C, which represents roughly a three-fold amplification of the global climate signal.

To evaluate the magnitude of climate change impacts, recent data covering large and representative areas are needed. This paper is aimed at contributing to describe the recent evolution of Alpine glaciers by analysing surface area changes in a representative subset of data (34 glaciers located in the Adamello Group, Lombardy, Italy).

Four surface area records, for the years 1983, 1991, 1999 and 2003, were analysed. The 1983, 1999 and 2003 surface area records were compiled by the authors by combining aerial photo analysis, Differential Global Positioning System (DGPS) surveys of glaciers and Geographic Information System (GIS) data processing. The analysis led to a quantification of surface reduction: c. 19% from 1983 to 2003 for glaciers in the Adamello group, Lombardy, Italy.

Small glaciers proved to contribute strongly to total area loss: in 2003, 31 glaciers (c. 91% of the total number) were smaller than 1 km², covering 2.28 km² (c. 10% of the total area), but accounted for 39% of the total loss in area (losing 2.05 km² from 1983 to 2003). The rate of area change accelerated in the later period, with surface reduction between 1999 and 2003 amounting to c. 5.5% (with respect to the 1999 total glacier coverage), equal to a mean area loss of c. 0.34 km²/year; the mean yearly loss over the previous period (1991-1999) was found equal to 0.23 km²/year. This acceleration coincided with a clear local warming and a small local decrease in snow cover depth and duration which resulted strongly related to North Atlantic Oscillation (NAO) winter variability.

Key Words: Glacier shrinkage, Climate change impacts, Italian Alps.


I ghiacciai dell’intero pianeta stanno mostrando ampie evidenze degli impatti del Cambiamento Climatico. Nella regione alpina il riscaldamento registrato sin dai primi anni 80 (del XX secolo), sebbene sia avvenuto in sincronia con quello manifestatosi a scala globale, è stato di maggiore intensità ed ha anche superato 1°C, valore che rappresenta un’amplificazione circa tripla del segnale climatico globale.

Al fine di valutare l’intensità degli impatti del Cambiamento Climatico sono necessari dati recenti relativi ad aree estese e rappresentative. Questo articolo è finalizzato a contribuire alla conoscenza dell’evoluzione recente dei ghiacciai alpini attraverso l’analisi delle variazioni areali di un campione rappresentativo di ghiacciai (34 apparati localizzati nel Gruppo dell’Adamello, Lombardia, Italia).


I ghiacciai di minori dimensioni sono risultati tra i maggiori responsabili della perdita areale totale: i 31 ghiacciai che nel 2003 (pari a c. il 91% del numero totale) risultavano più piccoli di 1 km² e si estendevano in totale per 2.28 km² (circa il 10% dell’area totale) hanno portato a perdite areali per circa il 39% (pari a ~2.05 km²). Il ritiro areale ha visto nel l’ultimo periodo un’intensa accelerazione: la riduzione di superficie glaciale tra il 1999 ed il 2003 assomma a c. il 5.5% (calcolato rispetto al...
INTRODUCTION

The worldwide retreat of glaciers from Alpine areas (Haeberli & Beniston, 1998) to Antarctica (Rott & alii, 1996; Cook & alii, 2005), during the last few decades, is frequently mentioned as a clear and unambiguous sign of global warming (Oerlemans, 2005; IPCC, 2007). Atmospheric warming in the Alps has been found to be stronger and clearer in comparison to other sites (Böhm & alii, 2001), with significant summer warming, which has been particularly severe since 1970 (Casty & alii, 2005).

As a result of this rapid climate evolution, many small glaciers (i.e., glaciers with a surface area < 1 km²) located at mid elevation could disappear in the next few decades (Zemp & alii, 2006). These small glaciers are common in the Alps, where they represent 80% of the total glacial number and constitute an important contribution to water resources (Oerlemans & Fortuin 1992) (See also the alone Apenninic Glacier, Ghiacciaio del Calderone, Pecci & alii, 2008).

The rapid shrinkage of Alpine glaciers has already been noted and discussed in an analysis of the Swiss Glacier Inventory of 2000 by Paul & alii (2004). According to this study, 44% of the area loss between 1973 and 1998/1999 refers to glaciers with lengths of less than 1 km and covering only 18% of the total area in 1973 (Paul & alii, 2004). Citterio & alii, 2007, reported analogous results by analysing Lombardy glaciers in the 1991-1999 period. Therefore small glaciers are showing a higher sensitivity than larger ones, due to their very rapid reaction time (sensu Haebel & Hoelzlé, 1995) and are therefore suitable sites for the assessment and monitoring of climate change impacts (Dyurgerov & Meier, 2000).

Various types of studies can be performed to analyze the ongoing evolution of glaciers, including the data collection and analysis of parameters typically considered in glacier inventories (e.g. glacier area), which can be used to investigate mountain glaciers in a changing climate (Paul & alii, 2004), and potential scenarios on the regional Alpine scale (Zemp & alii, 2006). Comparison of various glacier inventories makes it possible to draw a general picture of the changes that have taken place in a glacier region in the past decades. Repeated glacier inventories should be carried out at intervals that are compatible with the characteristic dynamic response times of mountain glaciers (a few decades or less in the case of small glaciers). However, the current glacier down-wasting observed in several mountain areas probably calls for more updates of inventories at shorter time intervals (Paul & alii, 2007). A recent and updated glacier inventory covering the whole glacierized area of the Italian Alps is lacking; the last inventory dates back to 1989 (Biancotti & Motta, 2000) and enables comparison only with the previous one (CNR-CGI, 1961).

In this paper, in order to contribute to the knowledge of the recent changes affecting Italian glaciers, surface area changes of a representative subset of data (34 glaciers located in Adamello Group, Lombardy) were calculated and analyzed. Four area records (1983, 1991, 1999 and 2003) were available for this study, thus allowing quantification of not only glacier changes, but also variations of their rates over time so as to look for any increasing-decreasing trend.

In addition, in this contribution attention is paid to local climate trends and their relations with the global tendency in order to look for evidence of climate changes and, if any, to evaluate their magnitude.

STUDY AREA

The Adamello Group represents an important glacialized subregion (c. 24.6% of Lombardy glacier coverage is located here) that can be considered representative of Italian glaciation (fig. 1). In fact, not only it includes Italy’s largest glacier (i.e., Adamello Glacier, with an area of about 18 km²), but also many medium and small glaciers with a wide range of settings, aspects, altitudes and surface slopes. In the Adamello group the main glacier type is the mountain glacier, representing 80% of the total number. The Adamello area represents an important study site and previous authors completed several studies deepening on understanding of the relations among geomorphological evidences and glacier variations (among others Baroni & Carton, 1987).

DATA SOURCES AND METHODS

Four surface area records, dated 1983, 1991, 1999 and 2003, are available for the Adamello glaciers. We compiled the 1983, 1999 and 2003 records by defining glacier outlines on colour aerial photographs (1983, 1999 and 2003 flights) and reporting them in a GIS environment. The 1991 data base, instead, was compiled by previous authors (SGL, 1992).

As regards the 1983 area record, it was obtained by analysing with an optical stereoscopic system the 1983 aerial photos (at a scale of c. 1:20,000) to obtain a 3D view of the glacierized area. Then the glacier limits observed on the photos were reported as polygons in a GIS environment. The 1:10,000 scale Technical Regional Map (CTR) of Lombardy Region was used as raster base. The topographic data reported in the CTR are referred to the same period as the aerial photos (1983), thus enabling evaluation of the reliability and accuracy of our findings. The planimetric accuracy of the 1983 source of data was found equal to ± 5 m. The 1999 and 2003 records, instead, were obtained by combining glacier outlines manually